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Estimation of animal and olive solid wastes in Jordan and their potential as a supplementary energy source: An overview

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ABSTRACT

Biomass is a potential source of energy that can reduce our dependency on oil as the main source of energy. In addition to municipal solid waste, animal and olive wastes are the main sources of organic waste in Jordan. In 2005, there were more than 2.4 million heads of sheep, about 72 thousand cows, and 40 million hens being raised in farms distributed in all governorates of Jordan. These animals produce 5.3 million tons (as exerted) of solid waste per year. If these quantities can be effectively collected they may constitute a valuable source of energy. This paper is aiming to estimate the amounts of animal and solid wastes generated in Jordan and their energy potential.

The total amount of BOD from animal waste is estimated at 200,000 tons per year. Significant quantities of organic waste can also be collected from olive mills distributed in the country. This waste known locally as "Jift" is currently being collected and used for heating during the winter. The amount of olive waste produced in 2005 was about 27,000 tons. The potential for energy recovery from these wastes was investigated. Assuming an overall waste collection efficiency of 70%, the total heating value of these wastes was found to be 6600 million MJ. This quantity is equivalent to 157 thousand tons of oil equivalent (toe). This quantity represents 84% of Jordan's local crude oil and natural gas production. However, it only represents 2% of the total primary energy consumption of 7187 thousand toe. In addition, the scattering of farms and olive mills in the country will make the collection of their waste costly. Therefore, any potential project for energy recovery from animal and olive wastes in a centralized plant may have low economic merit; however, its environmental benefits are tangible. Decentralized collection and processing of these wastes may be a better option.

Contents

1. Introduction

The exploding world's population and the expanding industrial developments led to an increase in the consumption of conventional energy sources to alarming levels. Oil has been the major source of energy for most industrial developments. However, most experts agree that the oil reserves will be depleted in the near

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future. In addition, the continuously increasing oil prices burdened the world's economy. Recognizing these problems, the search for alternative and clean energy sources evolved as a priority for most developed nations. One of these alternatives is to convert biomass to energy. Many researches investigated the energy content of different types of biomass and their feasibility as an alternative source of energy.

Biomass resources include forest and mill residues, agricultural crops and wastes, wood and wood wastes, animal wastes, livestock operation residues, aquatic plants, fast-growing trees and plants, and municipal and industrial wastes. Biomass is the third largest primary energy in the world, after coal and oil. It remains the primary source of energy for is about 14% of the world's annual energy consumption [1]. Projections of final biomass energy consumption in developing countries is projected to continue to increase, rising from 825 million tons of oil equivalent (Mtoe) in 1995 to 1071 Mtoe in 2020 [1].

Biomass can be used in its solid form or gasified for heating, applications or electricity generation, or it can be converted into liquid or gaseous fuels. The use of biomass to produce heat and power can be environmentally beneficial because biomass is a renewable resource and its combustion does not contribute additional greenhouse gases to the atmosphere.

Cantrell et al. [2] reviewed the current biological and thermal technologies for livestock waste conversion into energy. They suggested a hybrid bio-thermal system that is capable to treat livestock waste while at the same time reduce the greenhouse gas emissions and produce energy.

Tricase and Lombardi [3] analyzed the current status and prospects of Italian biogas production from animal waste. They estimated that the total available animal waste is about 132 millions m^3/year, which is capable to produce approximately 2.2 Gm^3/year of biogas. In order to make the energy production from biomass technically and economically feasible, the authors recommended a reform of legal framework.

Table 1
Weight of animals and factors used to calculate the amount of waste.

Animal	W (Ib)	f_W (Ib/d/1000)	f_{VS} (Ib/d/1000)	f_{BOD_5} (Ib/d/1000)
Ovine	132	40	8.3	1
Goat	110	40	8.3	1
Veal	1984	60	0.85	0.37
Dairy cow	1323	81	8.3	1.4
Heifer	992	85	7.77	1.3
Layer	3.3	60.5	10.8	3.7
Broiller	4.4	80	15	5.1

In Jordan, the energy bill is a burden for the government and the people. Providing adequate and clean energy is considered to be one of the main challenges for sustainable development in Jordan. Biomass may be a feasible energy source that can reduce the country's dependency on imported oil. The main sources of biomass in Jordan are the animal waste and the olive waste known locally as "Jift". Preliminary studies carried out by the National Energy Research Centre of Jordan show that biogas from animal and domestic waste can save up to 4% of imported oil which is equivalent to 130,000 toe per annum [4].

This study aims at estimating the quantities of animal and olive wastes and determining their characteristics and geographic distribution. Further, the potential for energy recovery from these wastes will be assessed.

2. Animal waste quantities and characteristics

Animal waste collected in concentrated feed lots can cause significant environmental problems if it is not managed properly. One management option is its reuse as a potential source of energy.

Table 2
Amount of sheep waste distributed in the Governorates of Jordan calculated as weight, volatile solids and biochemical oxygen demand.

Governorates	Sheep	No. of heads	W (Ib/year) $\times 10^6$	Total W %	VS (Ib/year) $\times 10^6$	BOD_5 (Ib/year) $\times 10^6$
Amman	Ovine	255,170	493	13.61%	102.3	12.3
	Goat	74,660	120		24.9	3.0
Madaba	Ovine	98,170	190	5.28%	39.3	4.7
	Goat	29,740	48		9.9	1.2
Zarqa	Ovine	122,550	237	6.83%	49.1	5.9
	Goat	43,830	71		14.6	1.8
Balqa	Ovine	85,860	166	5.63%	34.4	4.1
	Goat	54,350	87		18.1	2.2
Irbid	Ovine	99,680	193	5.97%	39.9	4.8
	Goat	47,180	76		15.8	1.9
Jarash	Ovine	6570	13	1.14%	2.6	0.3
	Goat	23,940	39		8.0	1.0
Ajloun	Ovine	4390	8	0.66%	1.8	0.2
	Goat	13,100	21		4.4	0.5
Mafraq	Ovine	896,330	1730	40.90%	359.2	43.3
	Goat	69,560	112		23.2	2.8
Karak	Ovine	156,140	302	9.75%	62.6	7.5
	Goat	85,290	137		28.5	3.4
Tafieleh	Ovine	60,400	117	3.26%	24.2	2.9
	Goat	18,560	30		6.2	0.7
Ma'an	Ovine	94,670	183	5.09%	37.9	4.6
	Goat	28,800	46		9.6	1.2
Aqaba	Ovine	21,230	41	1.88%	8.5	1.0
	Goat	27,130	44		9.1	1.1
Total (Ib/year)		4500×10^6		934×10^6	113×10^6	
Total (ton/year)		2,041,200		424,100	51,100	

In 2005, there were more than 2.4 million heads of sheep, about 72 thousand cows, and 40 million hens being raised in farms distributed in all governorates of Jordan [5]. These produce huge quantities of waste that are currently being collected and disposed or reused locally as a natural fertilizer.

The numbers of animals in Jordan by the end of 2005 are used to calculate the amount of wastes produced per year using estimates for average weight (W), volatile solids content (VS), and biochemical oxygen demand (BOD_5). Values of W were obtained from the Ministry of Agriculture, while estimates of VS and BOD_5 were taken from the Agricultural Waste Management Field Handbook, published by the U.S. Department of Agriculture, Soil Conservation Service (now the Natural Resources Conservation Service), April, 1992. The following equation is used in these calculations.

$$X = W \times f_X \times N \times 365 \quad (1)$$

where X, weight or VS or BOD5; W, weight of animal in Ib; f_X, one of the factors (f_W, f_{VS}, or f_{BOD_5}) based on X. N, number of animals (Table 1).

2.1. Sheep waste

The number of sheep heads in Jordan was estimated by the end of 2005 to be about 2.4 millions including 1.9 million heads of ovine and (0.516) million heads of goats. About 40% of the sheep are raised by farmers in Mafraq Governorate.

Table 2 shows the amount of sheep waste, the total and volatile solids, and the organic load (BOD_5) for all governorates. The results indicate that about 2 million tons (as exerted) of sheep waste can be generated per year. However, the actual amount of waste collected is in Jordan is less than one quarter of this quantity because the sheep are assumed to be raised in barns only during the winter months. Similarly, the actual amounts of total solids, volatile solids, moisture, and BOD_5 are also expected to be one quarter of the values estimated in Table 2.

2.2. Cows waste

The number of cows in Jordan by the end of 2005 was 71,753 heads distributed based on type as shown in Table 3. The numbers of cows are used to calculate the amount of wastes produced per

Table 3
Amount of cow waste distributed in Jordan calculated as weight, volatile solids and biochemical oxygen demand (BOD_5).

Governorate	Cow	No. of heads	W (Ib/year) $\times 10^6$	Total W %	VS (Ib/year) $\times 10^6$	BOD_5 (Ib/year) $\times 10^6$
Amman	Veal	93	4.0	9.50%	0.1	0.0
	Dairy	5283	207.0		21.2	3.6
	Heifer	1321	40.7		3.7	0.6
Madaba	Veal	19	0.8	1.67%	0.0	0.0
	Dairy	766	30.0		3.1	0.5
	Heifer	436	13.4		1.2	0.2
Zarqa	Veal	352	15.3	40.75%	0.2	0.1
	Dairy	20,283	793.0		81.3	13.7
	Heifer	8819	271.0		24.8	4.2
Balqa	Veal	90	3.9	7.42%	0.1	0.0
	Dairy	3560	139.0		14.3	2.4
	Heifer	1743	53.6		4.9	0.8
Irbid	Veal	164	7.1	15.44%	0.1	0.0
	Dairy	8711	341.0		34.9	5.9
	Heifer	1977	60.9		5.6	0.9
Jarash	Veal	33	1.4	4.65%	0.0	0.0
	Dairy	2759	108.0		11.1	1.9
	Heifer	449	13.8		1.3	0.2
Ajloun	Veal	8	0.3	1.80%	0.0	0.0
	Dairy	995	38.9		4.0	0.7
	Heifer	275	8.5		0.8	0.1
Mafraq	Veal	173	7.5	17.31%	0.1	0.0
	Dairy	8379	328.0		33.6	5.7
	Heifer	4002	123.0		11.3	1.9
Karak	Veal	5	0.2	1.34%	0.0	0.0
	Dairy	627	24.5		2.5	0.4
	Heifer	346	10.6		1.0	0.2
Tafieleh	Veal	0	0.0	0.09%	0.0	0.0
	Dairy	64	2.5		0.3	0.0
	Heifer	0	0.0		0.0	0.0
Ma'an	Veal	0	0.0	0.00%	0.0	0.0
	Dairy	0	0.0		0.0	0.0
	Heifer	0	0.0		0.0	0.0
Aqaba	Veal	0	0.0	0.03%	0.0	0.0
	Dairy	7	0.3		0.0	0.0
	Heifer	14	0.4		0.0	0.0
Total (Ib/year)		2649×10^6		261.2×10^6	44.1×10^6	
Total (ton/year)		1,201,500		118,500	20,000	

Table 4
Distribution of poultry waste in Jordan calculated as weight, volatile solids and biochemical oxygen demand (BOD_5).

Governorate	Poultry	No. of birds	W (Ib/year) $\times 10^6$	Total W %	VS (Ib/year) $\times 10^6$	BOD5 (Ib/year) $\times 10^6$
Amman	Layer	2,336,590	171.0	22.75%	30.5	10.4
	Broiler	6,672,650	859.0		161.1	54.8
Madaba	Layer	185,600	13.6	5.54%	2.4	0.8
	Broiler	1,843,300	237.0		44.5	15.1
Zarqa	Layer	6,218,000	454.0	11.98%	81.1	27.8
	Broiler	684,800	88.2		16.5	5.6
Balqa	Layer	654,380	47.8	9.01%	8.5	2.9
	Broiler	2,796,300	360.0		67.5	23.0
Irbid	Layer	1,170,660	85.6	15.94%	15.3	5.2
	Broiler	4,939,800	636.0		119.3	40.6
Jarash	Layer	181,600	13.3	3.45%	2.4	0.8
	Broiler	1,107,500	143.0		26.7	9.1
Ajloun	Layer	11,500	0.8	1.74%	0.2	0.1
	Broiler	606,500	78.1		14.6	5.0
Mafraq	Layer	2,124,700	155.0	17.89%	27.7	9.5
	Broiler	5,083,980	655.0		122.8	41.7
Karak	Layer	148,500	10.9	8.24%	1.9	0.7
	Broiler	2,811,070	362.0		67.9	23.1
Tafieleh	Layer	31,000	2.3	1.16%	0.4	0.1
	Broiler	391,800	50.5		9.5	3.2
Ma'an	Layer	198,000	14.5	0.81%	2.6	0.9
	Broiler	173,000	22.3		4.2	1.4
Aqaba	Layer	5000	0.4	1.48%	0.1	0.0
	Broiler	517,120	66.6		12.5	4.2
Total (Ib/year)		4527×10^6		840×10^6	286×10^6	
Total (ton/year)		2,053,200		381,100	129,800	

year using estimates for average weight, volatile solids content, and biochemical oxygen demand (BOD_5). Table 3 shows the amount of cows waste, the total and volatile solids, and the organic load (BOD_5) for all governorates. About 41% of these cows are raised in dairy farms located in Zarqa Governorate producing a similar percentage of waste.

2.3. Poultry waste

By the end of 2005, there were 2618 chicken farms in Jordan. About 84% of these farms are for broiler chicken. The number of birds contained in all types of chicken farms was about 41 million. The governorates of Amman and Mafraq have the highest number of birds containing 23% and 18%, respectively. Table 4 shows the number of birds in all governorates classified into layers and broilers.

The number of birds given in Table 4, are then used to calculate the amount of poultry waste produced per year using estimates for average weight, moisture content, volatile solids content, and biochemical oxygen demand (BOD_5). The results show the amount of poultry waste, the total and volatile solids, and the organic load (BOD_5) for all governorates.

2.4. Olive waste

In 2005, there were 97 olive mills distributed throughout the country as shown in Table 5. These mills received 107,000 tons of olives and produced 20,300 tons of oil. About 39% of these mills are

Table 5
Distribution of olive mills, and waste production in Jordan in 2005.

Governarates	No. of mills	Olive processed by mills (ton)	Oil production (ton)	Olive waste (ton)	Olive waste (%)
Amman	5	7681	1604	1920	7%
Madaba	2	1778	336	445	2%
Alzarqa	4	16,650	3243	4163	16%
Irbid	37	31,093	5442	7773	29%
Jarash	14	9362	1871	2341	9%
Ajlun	11	7352	1471	1838	7%
Almafrak	8	14,990	2797	3748	14%
Albalqa	8	11,686	2492	2922	11%
Alkarak	3	1645	313	411	2%
Altafilah	2	640	147	160	1%
Ma'an	2	3027	411	757	3%
Aqaba	1	846	140	212	1%
Total	97	106,750	20,267	26,688	100%

Table 6
Heating value of animal and olive wastes in Jordan.

Waste type	Weight (ton/year)	Moisture content (%)	Dry weight (ton/year)	Heating value (MJ/kg)	Total heating value $\times 10^6$ (MJ)
Sheep	2,041,200	75	127,575[a]	16.9	2156
Cow	1,201,500	90	30,040[a]	12.3	369
Poultry	2,053,200	75	513,300	12.3	6314
Olive	26,688		26,688	22	587
Total $\times 10^6$ (MJ)	9426				

[a] Assuming that animals are kept in barns only for three months.

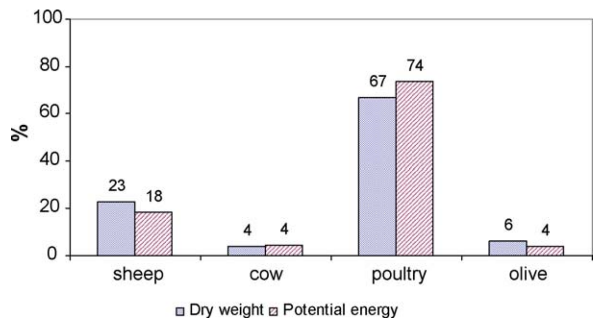


Fig. 1. Percentage of dry weight of solid waste and potential energy from animal and olive wastes in Jordan.

located in the governorate of Irbid, receiving 29% of the total olive production and yielding 27% of the country's oil production.

Professionals in olive oil industry estimate the dry olive waste production to be 25% of the olive production. Hence the amount of olive solid waste produced in 2005 was around 27,000 tons. As shown in Table 5, about 29% of the olive waste was produced in the governorate of Irbid.

3. Animal and olive wastes heating values

An Isoperiobolic Bomb Calorimeter was used in determining the waste calorific value. The calorimeter is fitted with an embedded control computer enabling automation of much of the calibration and test procedures via the key pad. Samples of animal and olive wastes were dried in an oven at 105 °C for 24 h. Dry samples were grinded and mixed thoroughly and subdivided to obtain a working sample quantity of 10 g from each waste. A waste sample of 1 g was placed into a crucible that was introduced into the calorimeter bomb with appropriate firing wire. Then the bomb covered is tightly sealed and connected to oxygen filling fitting and placed in the calorimeter bucket. The bucket was then placed into the water jacket after which it is connected to the firing circuit plugs and firing was accomplished, and the calorific value was determined. On per mass basis, olive waste has the highest heating value at 22 MJ/kg followed by sheep waste at 16.9 MJ/kg.

4. Estimation of potential energy recovery from animal and olive wastes

Significant quantities of animal and olive wastes are produced annually in Jordan. As shown in Table 6, the heating value of each waste was determined. Fig. 1 shows that poultry waste constitutes 67% of the total animal and olive wastes produced in Jordan and its potential energy value is 74% of the total energy potential of animal and olive wastes energy.

The total heating value of animal and olive wastes was found to be 9426 million MJ. However, not all the waste can be collected. Assuming an overall waste collection efficiency of 70%, about 6600 million MJ can be obtained.

The ton of oil equivalent (toe) is a unit of energy: the amount of energy released by burning one ton of crude oil, approximately 42 GJ. Therefore, the energy of animal and olive wastes in Jordan is equivalent to 157 thousand toe. This quantity represents 84% of Jordan's local crude oil and natural gas production. However, it only represents 2% of the total primary energy consumption of 7187 thousand toe [6].

5. Conclusions

Significant quantities of organic waste including animal and olive wastes can be collected from farms and olive mills distributed in all Jordan's governorate. These quantities are partially being collected and reused as a natural fertilizer. Reuse of these wastes as a supplementary source of energy is currently very limited. The heating value of these wastes was determined. On per mass basis, olive waste has the highest heating value at 22 MJ/kg. Poultry waste constitutes 67% of the total animal and olive wastes produced in Jordan and its potential energy value is 74% of the total.

The total heating value of animal and olive wastes was about 6600 million MJ which represents 2% of the total primary energy consumption in Jordan. In addition, the scattering of farms and olive mills in the country will make the collection of their waste costly. Therefore, any potential project for energy recovery from animal and olive wastes in a centralized plant may have low economic merit; however, its environmental benefits are tangible. Decentralized collection and processing of these wastes may be a better option.

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